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FUMIGATION OF ORNAMENTAL GREENHOUSE PLANTS WITH HYDROCYANIC-ACID GAS.

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INTRODUCTION.

Hydrocyanic-acid gas, if intelligently employed, is one of the cheapest and most efficient methods of controlling thrips, aphids, white flies, and various scale insects on plants grown under glass. That this method of control has not been generally adopted is no doubt owing to the deadly poisonous nature of the gas if inhaled, its disastrous effect on tender plants if improperly used, and the pre-

NOTE.—Hydrocyanic-acid gas was first used against greenhouse pests in 1895 by Messrs. A. F. Woods and P. H. Dorsett (see Circular No. 37, Bureau of Entomology, U. S. Department of Agriculture) in an effort to destroy insects on diseased plants under observation. Subsequently others have employed the gas in greenhouse fumigation, but with varying success, largely because of inexperience and improper methods of procedure. In the earlier experiments in greenhouses conducted by the Bureau of Entomology the senior author was assisted by Mr. H. L. Sanford, of the Federal Horticultural Board, and by Messrs. Eugene May, W. R. Lucas, and Charles Keller, of the Bureau of Plant Industry. The spelling of the botanical names used in this publication has been verified by Messrs. P. L. Ricker and H. C. Skeels.

CAUTION.—*Hydrocyanic-acid gas is colorless and is one of the most deadly poisonous gases known. It has an odor much like that of peach pits. In case of accidental inhalation of the gas, the person affected should be kept in the open air and required to walk to increase respiration.*

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vailing impression that fumigation is a cumbersome procedure requiring considerable skill on the part of the operator. While it is true that much damage to the plants and injury to the operator may result from the *careless* use of hydrocyanic-acid gas, it is an established fact that this fumigant in competent hands is a safe, practical, and economical means of controlling virtually all insect pests found in greenhouses.

EQUIPMENT NECESSARY FOR FUMIGATION.

GENERATORS.

One-half gallon or one-gallon glazed earthenware jars serve as satisfactory generators, although it is preferable that the bottoms of the jars be rounded inside, so that the cyanid will be covered with the acid and water, even with small doses, thus insuring the maximum generation of the gas. The number of generators required is largely influenced by the size of the house or houses to be fumigated, and to avoid unnecessary delay in case of breakage several extra crocks should be available.

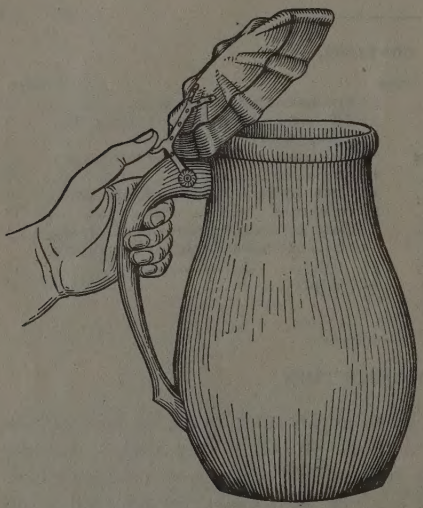

FIG. 1.—A cover device attached to a fumigation generator. Corrugations in cover allow gas to escape. (Woglum.)

To insure uniform distribution of the gas it is advisable to employ generators with covers, such as that illustrated in figure 1. This cover, which was designed by Mr. R. S. Woglum,[1] is made of copper stamped in a concave form with corrugations to permit the escape of the gas. It is attached to the generator by hinges and held in place by a bolt which extends through the handle and can be raised by a slight pressure of the thumb as shown in the figure. If it is not possible to secure crocks of this description, those with straight sides which are not constricted inside at the bottom can be used with good results, although to insure complete generation such a crock should be tilted slightly in order that the cyanid may be covered. Crocks

[1] Bul. 79, Bur. Ent., U. S. Dept. Agr., p. 58, fig. 21, 1909. Bul. 90, Part I, Bur. Ent., U. S. Dept. Agr., p. 75, fig. 12, 1911.

with straight sides are frequently sold with glazed earthenware tops. These tops or covers increase the cost of the generators and, furthermore, are useless for fumigation purposes. Therefore, when generators are ordered it should be indicated that tops are not desired. With this type of generator a cover may be improvised by using a piece of corrugated galvanized iron roofing or a board with cleats on the underside, to allow the free exit of gas.

MISCELLANEOUS REQUIREMENTS.

Correct scales or balances, reading in tenths of an ounce, are convenient for accurate work. An 8-ounce graduate is desirable for measuring the acid and water. To avoid splashing of the acid it should not be poured from a carboy or bottle into the graduate but should be transferred to a porcelain pitcher, from which it may be poured with safety. It is well to have on hand a supply of small bags or tissue paper in which to place the cyanid.

PREPARATION OF HOUSE FOR FUMIGATION.

As a preliminary to fumigating the house it is essential that the exposed glass surface be examined carefully and all broken glass replaced. All cracks should be thoroughly closed. The ventilators,

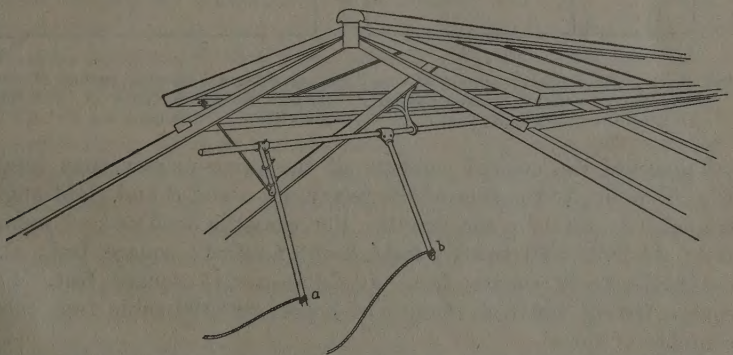

FIG. 2.—Methods of attaching rod and cord (*a*, *b*) to ventilator shaft of greenhouse so that the ventilators can be opened from the outside after fumigation. (Original.)

both side and top, where possible, should be so arranged that they can be opened on the outside of the house upon the completion of the exposure. This can be accomplished by disconnecting the "machine," or gear, of the top ventilators and attaching to the central ventilator shaft (see fig. 2) an arm (*a* or *b*) which can be controlled by a cord or wire which extends through the side of the house. The gears on the side ventilators may be disconnected so that the sash may be opened from the outside. If only one ventilator can be opened it is preferable that it be the one on the roof of the house.

METHOD OF COMPUTING THE CUBICAL CONTENTS OF EVEN AND THREE-QUARTER SPAN GREENHOUSES.

It is essential in every instance that the cubical contents of the house to be fumigated be determined accurately, and the following is a simple method of arriving at these figures: To facilitate matters a diagram indicating the necessary dimensions of the house should be made. (See figs. 3 and 4.)

To secure the cubical contents of the even-span house (fig. 4), compute the number of square feet in the rectangle *a* and in the right-angle triangles *b* and *c* and multiply the sum of the three by the length of the house. For example, A=5×20=100 square feet; B=5×10÷2=25 square feet[1]; and C=5×10÷2=25 square feet. A+B+C=150 square feet. 150 square feet × 100 feet (length of house)=15,000 cubic feet, cubic contents of the house.

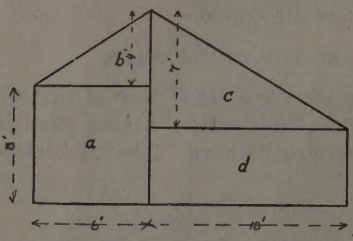

FIG. 3.—Diagram showing method of computing cubical contents of three-quarter-span greenhouse. (Original.)

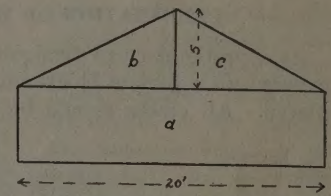

FIG. 4.—Diagram showing method of computing cubical contents of even-span greenhouse. (Original.)

To secure the cubical contents of the three-quarter span house (fig. 3) multiply the sum of the rectangles *a* and *d* and right-angle triangles *b* and *c* by the length. For example *a*=6×8=48 square feet; *d*=18×5=90 square feet; *b*=6×4÷2=12 square feet; and *c*=18×7÷2=63 square feet. *a*+*d*+*b*+*c*=213 square feet. 213 square feet × 100 feet (length of house)=21,300 cubic feet, cubic contents of house.

In estimating the cubic contents of a greenhouse it is not necessary to make allowances for the space occupied by the benches, pots, etc.

TIME FOR FUMIGATION.

Fumigation should be conducted not earlier than one hour after sunset and should not be attempted when the wind is high. It is undesirable to fumigate during extremely cold nights, when the thermometer is registering near zero, owing to the necessity of ven-

[1] To calculate the area of a right-angle triangle, multiply the base by the perpendicular and divide the product by two.

tilating the houses upon the completion of an exposure. It is inadvisable to fumigate on hot, humid nights, when the temperature in the house can not be lowered readily to the desired limit. The best temperature for fumigation is between 55° and 68° F.

The interval between fumigations naturally should be governed by the reappearance of the insect under control. With small dosages, which are imperative when fumigating a house containing an assortment of plants, it is possible to kill only the larvæ of scale insects, the adults and first larval stages of the greenhouse white fly, the adults of the Florida fern caterpillar, greenhouse leaf-tyer, and loopers, and a certain percentage of aphids. The eggs and pupæ of most greenhouse insects offer considerable resistance to hydrocyanic-acid gas, and furthermore the overlapping of broods necessitates several fumigations at short intervals. It has been proved repeatedly that three or four fumigations at short intervals will give practical control.

CHEMICALS REQUIRED FOR FUMIGATION.

The chemicals required in fumigating with hydrocyanic-acid gas are sodium cyanid (NaCN) or potassium cyanid (KCN), sulphuric acid (H_2SO_4), and water (H_2O). Potassium cyanid has been superseded recently by sodium cyanid in the generation of this gas, and the former is rarely used nowadays in fumigation. Sodium cyanid should be practically free from chlorin and contain not less than 51 per cent of cyanogen. It may be purchased either in lumps or in the shape of an egg, each "egg" weighing approximately 1 ounce. The latter is easily handled and the necessity of weighing each charge is obviated, providing, of course, the dosage is in ounces. For example, if the house requires 10 ounces of cyanid, 10 "eggs" are used. However, in small dosages, where the cyanid is measured in grams, it is necessary to use small lumps or break up the "eggs."

Cyanid is one of the most poisonous substances known and should be stored in air-tight cans, plainly labeled, and kept out of reach of those unacquainted with its poisonous nature.

Commercial sulphuric acid (about 1.84 sp. gr. or 66° Baumé) which is approximately 93 per cent pure is commonly used and gives very satisfactory results. The acid should be kept in a glass receptacle, properly labeled, and tightly corked with a glass stopper.

DETERMINING THE AMOUNT OF CYANID TO BE USED.

Satisfactory results are obtained only where it is possible to overcome the resisting power of the insects without overcoming the resisting power of the plant. Tender succulent plants, such as roses, geraniums, coleus, sweet peas, Wandering Jew, etc., are more susceptible to injury by hydrocyanic-acid gas than are certain hardy ornamentals,

and this fact should be considered where an assortment of plants is to be fumigated. In case there is any doubt as to the amount of gas a plant will stand without injury, it is preferable that the initial dosage be not over one-fourth ounce of sodium cyanid per 1,000 cubic feet and increased with subsequent fumigations until the fatal point of the pest to be controlled is reached, it being borne in mind that in some instances it is not possible to effect an absolute control of all stages of some insects with one fumigation without injury to foliage or growing parts of certain plants. For example, the greenhouse white fly has been eradicated with three successive fumigations at intervals of 7 to 9 days, using one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet, in houses containing such susceptible plants as coleus, ageratum, heliotrope, fuchsia, etc., with no injury to the foliage. Moreover, such resistant pests as scale insects can be eliminated entirely by killing the immature stages with a small dosage repeated at frequent intervals.

Under favorable conditions houses which do not contain roses, rose geraniums, asparagus ferns, lemon verbena, snapdragon, Wandering Jew, or sweet peas can be fumigated with safety with an initial dosage of one-half ounce of sodium cyanid (NaCN) per 1,000 cubic feet.

To determine the total amount of cyanid to be used, ascertain from the tables on pages 12–18 the plants in your greenhouse which are most easily injured by the gas fumes and note the amount of cyanid which was used per 1,000 cubic feet with little or no injury to the plants. Then multiply the number of thousand cubic feet contained in the house by the amount of cyanid to be used per 1,000 cubic feet. For example, if one-half ounce of cyanid is to be used per 1,000 cubic feet, and the house contains 15,000 cubic feet, the total amount of cyanid necessary would be 7½ ounces.

In case there is any doubt as to the amount of gas the plant can stand without injury, the initial dosage, as previously stated, should not exceed one-fourth ounce per 1,000 cubic feet.

CHEMICAL FORMULA TO BE EMPLOYED.

The chemicals[1] should be mixed in the following proportions: For each ounce of sodium cyanid use 1½ fluid ounces of sulphuric acid and 2 fluid ounces of water.

[1] If potassium cyanid is used in place of sodium cyanid, the formula should be as follows: For each ounce of 98 to 99 per cent potassium cyanid containing 38.4 per cent cyanogen use 1 ounce of sulphuric acid and 3 ounces of water. The yield from 1 ounce of high-grade sodium cyanid is equivalent to the yield from 1⅓ ounces of high-grade potassium cyanid.

MIXING THE CHEMICALS.

After the generators have been distributed throughout the greenhouse, and before the chemicals have been mixed, the cyanid should be weighed accurately and the proper amount for each generator placed in a paper bag near the generator. The chemicals should be mixed invariably in the following manner: First, measure and place in each generator the amount of water required; second, measure and place in each generator the amount of sulphuric acid required; third, drop the cyanid into the diluted warm acid in each generator, close the covers, immediately leave the house, and post a danger sign on the closed door. The cyanid should be dropped gently, not thrown, into the generators, and the operator should begin at the generator farthest from the door and work toward the door. In case there are two rows of generators the cyanid should be dropped simultaneously by two operators. As little time as possible should elapse between the addition of the acid and the addition of the cyanid, as the heat which is liberated by the mixing of the acid and water assists in the generation of the gas.

The residue left in the generators after fumigation should be buried or poured into a sink and the generator washed before being stored for future operations.

NUMBER OF GENERATORS TO BE EMPLOYED.

The number of generators will depend largely upon the size of the house, and they should be so arranged that the gas will be uniformly distributed throughout the inclosure. To secure this advantage, it is advisable that a number of generators be used rather than one large generator. Generators should be spaced from 20 to 25 feet apart, and in case of a light wind a few extra generators should be placed on the windward side of the house. An ounce to each jar is as small a dose as is practicable, unless the generators are well rounded inside at the base or well tilted.

EXPOSURES.

Short exposures with a greater strength of gas have been found more satisfactory than a weaker strength of gas overnight. In fact, better results will be gained if the exposures do not exceed one to two hours. An exposure of one hour is satisfactory in most instances. Short exposures also have the additional advantage of permitting the house to become thoroughly aerated previous to the rising of the sun.

VENTILATION AFTER FUMIGATION.

If there is a light wind, a ventilation of 10 to 15 minutes, using side and top ventilation, will be sufficient and will not lower the house temperature to a dangerous point unless it is close to zero weather outside. If it is a still evening and the outside temperature is not below 32° F., a 20 to 30 minute ventilation is satisfactory.

In case it is necessary to enter the house shortly after ventilation to determine the temperature, the person entering should not remain any longer than is necessary.

EFFECTS OF WEATHER CONDITIONS ON FUMIGATION.

TEMPERATURE.

Much experimentation has proved that excessive heat and cold will affect the results of fumigation. In most instances it is not advisable to fumigate if the temperature in the frame exceeds 70° F., or if the temperature is less than 55° F. It is possible that a variation of five degrees from the latter temperature will not result in serious injury to the plants, providing, of course, that the plants are not affected by such a low temperature.

LIGHT.

Light unquestionably affects fumigation. It has been known for a long time that it is very undesirable to fumigate when the sun is high. Furthermore, recent experiments have demonstrated that some injury may result to plants which have been subjected to fumes if, on the following day, the sun is very bright.

MOISTURE.

The question of moisture has received considerable attention from various fumigators, and it appears to be the consensus of opinion that excessive moisture in the presence of the gas does not increase the injury to plants and plant products under fumigation. A large number of plants have been fumigated in boxes immediately after syringing, when the leaves were covered with a film of water, with apparently no injury to the plants, and the insects on the plants were successfully controlled, which corroborates the experience of Morrill,[1] Quaintance,[2] and Woglum.[3]

Hydrocyanic-acid gas is readily soluble in water, and as a result the presence of excessive moisture in greenhouses decreases the effectiveness of the gas and consequently lessens the possibility of injury to the plants by burning. Fumigation experiments have been

[1] Bul. 76, Bur. Ent., U. S. Dept. Agr., p. 12, 1908.
[2] Bul. 84, Bur. Ent., U. S. Dept. Agr., p. 24, 31, 1909.
[3] Bul. 90, Bur. Ent., U. S. Dept. Agr., p. 68, 1912.

conducted where the plants, beds, and walks were thoroughly soaked with water, and the injury which would be expected under normal conditions to such plants as cosmos, rose geraniums, roses, heliotropes, and *Asparagus plumosus* did not appear, nor were such insects as aphids and thrips appreciably affected. It is obvious, therefore, that in order to increase the effectiveness of the fumigation the plants should be syringed not less than four or five hours prior to the liberation of the gas, to avoid undue absorption of the gas by the water on the benches and walks.

The difference in the results noted above may be accounted for by the fact that in the case of box fumigation only the foliage was covered with a film of water, whereas in the case of the greenhouse experiments not only the foliage of the plants was covered with a film of water but the entire soil surface of the house was soaked, and the water undoubtedly absorbed much of the available gas, reducing the toxic effect of the gas on the plants and insects.

HUMIDITY.

Recent tests have demonstrated that a relatively high humidity (98 to 100), with temperature varying from 70° to 75° F., greatly increases the amount of injury to the foliage of the plants, whereas plants in the presence of a relatively high humidity (98 to 100), with a temperature of 60° to 65° F., do not exhibit injury in excess of that which would appear if the plants were fumigated with an excessive dosage under normal atmospheric conditions. It is apparent, therefore, that a relatively high humidity alone is not responsible for injury unless accompanied by temperatures exceeding 70° F.

ADVISABILITY OF A FUMIGATION BOX.

A fumigation box is desirable for two reasons, namely, for testing the amount of gas plants can stand without injury, and for ridding a limited number of potted plants of insects, and thus avoiding costly and laborious hand scrubbing of such plants. The size of the box will depend on the use to which it is to be put. A box with a capacity of 200 cubic feet can be used advantageously for nursery stock, palms, etc.

Plants to be fumigated in a box in the daytime should remain in the box with the door closed at least one hour before the gas is generated and should be shaded from the bright sunlight for at least two hours after the completion of the exposure.

HOW INSECTS ARE DISSEMINATED FROM HOUSE TO HOUSE.

Doubtless many houses become infested with insects through the agency of plants commonly referred to as "boarders." The practice of turning over home-grown plants to a florist to care for during the

absence of the owner on a vacation is prevalent over the entire country, and often results in establishing pests not hitherto known to occur on the florist's premises. If the trade requires such a practice, plants of this character should be cleaned thoroughly of insect pests before being placed with the regular stock of the greenhouse.

Insect infestations in greenhouses have been traced to the following sources: Infested plants brought in from cold frames or propagation beds which have not received proper attention; cuttings, plants, and buds received from other establishments; and imported foreign or domestic stock. Adults of the greenhouse white fly, grasshoppers, beetles, aphids, etc., may enter through open ventilators from other houses or gardens; cutworms, wireworms, white grubs, etc., may be brought into the house with the soil; and roaches, ants, sowbugs, millipeds, etc., are sometimes brought in with packages, or they may crawl into the house through small openings.

COST OF HYDROCYANIC-ACID GAS FUMIGATION.

The economy in the use of hydrocyanic-acid gas as a means of controlling aphids, white flies, thrips, and the common greenhouse scale insects is apparent from the following figures, which are based on current prices:

Aphids can be controlled with a single fumigation at the rate of one-fourth ounce per 1,000 cubic feet at a cost of approximately ½ cent per 1,000 cubic feet. Tobacco fumigation with standard tobacco paper costs from 1½ to 3 cents per 1,000 cubic feet, and to secure a satisfactory control the operation must be repeated several times. Standard nicotine soap solution costs from 1 to 3 cents per gallon, and 4 gallons are required to cover plants which would occupy 1,000 cubic feet of space.

The greenhouse white fly can be controlled in three successive fumigations at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet, with a total cost of 3 cents per 1,000 cubic feet for a complete control. Standard insecticides cost about 6 cents per 1,000 cubic feet for a single application, and fully four applications are required for a satisfactory control.

Thrips can be controlled on such plants as azaleas, lilies, and ferns with a single fumigation at the rate of one-half ounce of sodium cyanid per 1,000 cubic feet at a cost of 1 cent per 1,000 cubic feet. A single application of nicotine soap solution costs fully five times as much as the gas treatment and still gives only a partial control.

The common scale insects of greenhouses (excepting mealy bugs) can be controlled by fumigating the infested plants at the rate of three-fourths ounce of sodium cyanid per 1,000 cubic feet at a cost of 1½ cents per 1,000 cubic feet. The standard proprietary insecticides

commonly recommended for scale insects cost approximately 4 cents per gallon with an average cost of 16 cents per 1,000 cubic feet for each treatment. A 5 per cent homemade kerosene emulsion costs approximately one-half cent more per 1,000 cubic feet than does the gassing method, and gives very indifferent results.

The foregoing figures do not take into consideration the cost of labor. However, the time required for fumigation will not exceed the time required for the mixing and application of the sprays.

PRECAUTIONS.

Do not *guess* the amount of chemicals to be employed or the cubic contents of the house.

Do not fumigate plants in a greenhouse in daylight. (For box fumigation in daytime, see page 9.)

Do not fumigate when the temperature in the house is below 50° or above 70° F.

Do not leave the chemicals within reach of those unacquainted with their poisonous nature. Always have them properly labeled.

Do not handle the chemicals any more than is absolutely necessary, and always wash the hands thoroughly after doing so. It is well to have a pair of old gloves for this, and to use them for no other purpose.

Do not allow the acid to splash or drop on the clothing or skin.

Do not stay in the house any longer than is necessary to place the cyanid in the jars, and *never* enter a house charged with gas until it has been thoroughly aired.

Do not fail to post danger signs at all entrances before setting off the charge, and to see that the house is tightly closed.

Do not attempt to fumigate without adjusting the ventilators so that they may be operated from the outside.

Do not attempt to fumigate a large house alone.

Do not fumigate a frame adjoining a dwelling without notifying the occupants before fumigation and allowing them time to leave. Houses contiguous to fumigated frames should be aired thoroughly before the occupants are allowed to reenter.

Do not pour the water on the acid; pour the acid on the water.

Do not become negligent in any of the precautions; to do so may cause serious results.

PLANTS AND INSECTS FUMIGATED IN GREENHOUSES.

Table I is offered as a guide to those desiring to employ hydrocyanic-acid gas for controlling greenhouse pests. Space will not permit the inclusion of all plants which have been fumigated by the writers, but the table includes many ornamentals and a few tropical and subtropical plants commonly grown in greenhouses.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses.*

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				° F.			
Abutilon sp	½		1	70	Greenhouse white fly.	No burning	All stages except egg and late pupæ killed.
Do	¼		1	58	do	do	Do.
Do	⅛		1	68	do	do	Do.
Do	¼		1	56	do	do	Do.
Abutilon vitifolia	½		1	64	do	do	Do.
Do	¼		1	77	do	do	Do.
Acalypha sp	½		1	60		do	
Do	¼		1	64		do	
Do	⅛		1	60		do	
Achania sp		½	¾	52		do	
Do		¼	1			do	
Achyranthes sp	½		1	58		do	
Do	¼		1	64		do	
Do	⅛		1	55		do	
Do	¼		1	60		do	
Actinidia polygama		1½	1	73		Slight burning	
Adenocalymma cosmosum		5	¾	66		No burning	
Agave americana	¾		1	68		do	
Agave sp		½	½			do	
Ageratum sp	½		1	64		do	
Do	¼		1	58	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Do	½		1	64	do	do	
Do	¼		1	56	do	do	
Air plant	½		1	70	Aphids	do	100 per cent killed.
Do	¼		1	68	do	do	Do.
Albizzia sp		1½	1	73		Slight burning	
Aleurites sp		1½	1	73		do	
Alpinia nutans	½		1	62		No burning	
Do	¼		1	74		do	
Althaea sp		1½	½		Aphids	do	Do.
Amaranthus sp	¾		1	55		do	
Amaryllis sp	½		1	60		do	
Do	¼		1	70		do	
Do	⅛		1	68		do	
Annona cherimola		¾	½			do	
Annona sp		1½	1	73		Slight burning	
Antidesma bunius		1½	1	73		do	
Anthericum sp	½		1	60	Long scale	No burning	80 per cent killed.
Do	¼		1	64		do	
Do	⅛		1	60	Long scale	do	100 per cent killed.
Anthurium sp		¾	½			do	
Aralia guilfoylei	½		1	66		do	
Ardissia sp	½		1	62		do	
Do	¼		1	74		do	
Araucaria excelsa	½		1	66		do	
Do	¼		1	77		do	
Aristolochia sp		5	¾	66		do	
Artemisia sp	1½		1	73		Slight burning	
Artillery plant	½		1	70		No burning	
Asparagus plumosus	½		1	66		Tips burned	
Do	½		1	70		do	
Do	½		1	60		do	
Do	½		1	68		Severe burning.	
Asparagus sprengeri	½		1	60		Tender tips burned.	
Do	½		1	70		No burning	
Do	¾		1	68		Tender tips burned.	
Do	¾		1	55		do	
Aspidistra sp	½		1	62		No burning	
Do	¼		1	74		do	
Aster	½		1	62		do	
"Atamasco"	½		1	64		do	
Do	¼		1	76		do	
Atropa sp	½		1	64		do	
Do	¼		1	76		do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Aucuba japonica	¼		1	66		No burning	
Do	½		1	77		do	
Do	¾		1	68		do	
Avocado, see *Persea*.							
Azalea indica		5	¾	66		do	
Azalea sp	½		1	60	Thrips	do	95 per cent killed.
Do					Azalea lace-wing.	do	100 per cent killed.
Do	¾		1	60	Azalea Eriococcus.	do	50 per cent killed.
Do	¾		1	55		do	
Do		5	¾	52		do	
Do		7½	1			Slight burning	
Bamboo		1½	1	73		Slight burning.	
Banana	½		1	60		No burning	
Do	½		1	55		do	
Basanacantha sp		1½	1	73		Severe burning.	
Begonia argenteoguttata	½		1	60	Orthezia	No burning	70 per cent killed.
Do	½		1	64		do	
Do	½		1	60		do	
Begonia diadema	½		1	60		do	
Do	½		1	58		do	
Do	¾		1	56		do	
Begonia erfordii		5	¾	66		do	
Begonia manicata	½		1	60		do	
Do	½		1	58		do	
Do	½		1	56		do	
Begonia metallica	½		1	66		do	
Do	½		1	77		do	
Begonia ricinifolia	½		1	60		do	
Do	½		1	58		do	
Do	½		1	56		do	
Begonia saundersoni	½		1	58		do	
Do	½		1	64		do	
Do	½		1	56		do	
Do	½		1	60		do	
Begonia (Leopard)	½		1	66		do	
Do	½		1	77		do	
Begonia (Lorraine)	½		1	62		do	
Do	½		1	74		do	
Begonia (Rex)	½		1	66		do	
Do	½		1	77		do	
Berberis rehderiana	½		1	62		do	
Do	½		1	74		do	
Berberis thunbergii		1⅛	½		Aphids	Slight burning	100 per cent killed.
Berberis vulgaris		1⅛	½		do	do	Do.
Berberis sp		1½	1	73		do	
Belladonna	½		1	62		No burning	
Do	½		1	74		do	
Bougainvillea	½		1	58		do	
Do	½		1	60		do	
Do	½		1	56		do	
Bradburya		1½	1	73		Slight burning.	
Bromelia sp		1½	1	73		Severe burning.	
Bunchosia sp		1½	1	73		Slight burning.	
Buxus sp. (boxwood)		5	¾	52		No burning	
Do		7½	1			do	
Cactus	½		1	70		do	
Do	½		1	68		do	
Calla lily	½		1	64		do	
Do	½		1	76		do	
Do		5	¾	66		do	
Caladium sp	½		1	55		do	
Do		⅝				do	
Camellia japonica		5	¾	52		do	
Camellia sp	½		1	55		do	
Do		7½	1			do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Camoensia sp		1¾	1	73		Slight burning.	
Canaga odorata	½		1	66		No burning	
Do	¾		1	77		do	
Canna	½		1	64		do	
Do	¾		1	77		do	
Carica papaya		1¾	1	73		Slight burning	
Carissa carandas		⅜	½			No burning	
Do		1¾	1	73		Slight burning.	
Carnation	½		1	62		No burning	
Do	¾		1	76		do	
Do	¾		1	55		do	
Cassia beareana		1¾	1	73		Slight burning.	
Cassia fistula		1¾	1	73		do	
Catha edulis	½		1	66		do	
Do	¾		1	77		do	
Ceiba pentandra		1¾	1	73		do	
Centaurea	½		1	60	Onion thrips	do	95 per cent killed.
Cereus (night-blooming)	½		1	64		No burning	
Do		¾	½			do	
Ceropegia thorncroftii		1¾	1	73		Severe burning.	
Chrysanthemum	½		1	62		do	
Do	¾		1	76	Aphids	do	100 per cent killed.
Do	¾		1	68		do	
Do		5	⅜	66		do	
Cigar plant	½		1	70	Aphids	do	Do.
Do	¾		1	68		do	
Cineraria	¾		1	60		Old foliage burned.	
Cinnamomum camphora	½		1	66		No burning	
Do	¾		1	77		do	
Do	¾		1	68		do	
Citrus aurantium	¾		1	60	Long scale	do	80 per cent killed.
Do	¾		1	55		do	
Citrus plumbago		5	⅜	52		do	
Citrus sp	½		1	64		do	
Do		1¾	½		Florida red scale.	do	90 per cent killed.
Do		7½	1			do	
Do		10	1½			Tender foliage burned.	
Clianthus dampieri	½		1	62		No burning	
Do	¾		1	74		do	
Clerodendron		5	⅜	66		do	
Cockscomb	½		1	64		do	
Coleus (Black Prince)	½		1	60	Orthezia	do	75 per cent killed.
Do	¾		1	66	do	Old foliage burned.	80 per cent killed.
Coleus (Firebrand)	½		1	60	do	No burning	75 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Golden bedder)	½		1	60	do	do	75 per cent killed.
Do	¾		1	60	do	Old foliage burned.	80 per cent killed.
Coleus (Golden Queen)	½		1	60	do	No burning	75 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Mrs. Hayes)	½		1	60	do	do	70 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Pfeister Red)	½		1	60	do	do	70 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Pfeister Yellow)	½		1	60	do	do	70 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Rose Bank)	½		1	60	do	do	70 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.
Coleus (Shirrock Jr.)	½		1	60	do	do	70 per cent killed.
Do	¾		1	60	do	Old foliage burned.	80 per cent killed.
Coleus (Queen Victoria)	½		1	60	do	No burning	70 per cent killed.
Do	¾		1	60	do	do	80 per cent killed.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Coleus (Verschaffelti)	¼	.....	1	60	Orthezia	No burning	70 per cent killed.
Do	⅜	.....	1	60	do	do	80 per cent killed.
Coleus (mixed)	¼	.....	1	64	do	do	100 per cent killed.
Coreopsis	¼	.....	1	62		do	
Cosmos	½	.....	1	60		Tips burned	
Do	.....	1⅛	1	73		Slight burning	
Cotton	¼	.....	1	66		No burning	
Do	⅜	.....	1	77		do	
Do	.....	⅛	½	.....	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Croton (mixed varieties)	¼	.....	1	58		do	
Do	⅜	.....	1	77		do	
Do	½	.....	1	56	Long scale	do	100 per cent killed.
Do	.....	1⅛	½	.....		do	
Cudrania javanensis	.....	1⅛	1	73		Slight burning	
Cudrania tricuspidata	.....	1⅛	1	73		do	
Cyclamen	¼	.....	1	58		No burning	
Do	⅜	.....	1	74		do	
Do	½	.....	1	68		do	
Cyphomandra sp	.....	1⅛	1	73		Slight burning	
Daffodil	¾	.....	1	55		No burning	
Do	.....	1⅛	1	73		Severe burning of new foliage.	
Deutzia gracilis	.....	1⅛	½	.....	Aphids	No burning	100 per cent killed.
Deutzia scabra	.....	1⅛	½	.....		do	
Digitalis	¼	.....	1	62		do	
Do	⅜	.....	1	74		do	
Dioscorea pentaphylla	½	.....	1	64		do	
Do	½	.....	1	76		do	
Dracaena godseffiana	.....	5	¾	66		do	
Dracaena indivisa	.....	5	¾	52		do	
Do	.....	7½	1	.....		do	
Enteleа palmata	.....	1⅞	1	73		Slight burning	
Erica sp	¼	.....	1	64		No burning	
Do	½	.....	.....	76		do	
Epiphyllum sp	¼	.....	1	64		do	
Do	½	.....	1	76		do	
Eupatorium sp	¼	.....	1	58		do	
Do	½	.....	1	60		do	
Do	.....	1⅛	1	73		Severe burning of young foliage.	
Ferns:[1]							
Adiantum cuneatum	¾	.....	1	60		No burning	
Adiantum croweanum	¾	.....	1	60		do	
Birds nest	¼	.....	1	70		do	
Do	¾	.....	1	68		do	
Boston	½	.....	1	60		do	
Do	¾	.....	1	68		do	
Holly	.....	5	¾	52		do	
Do	¼	.....	1	62		do	
Do	¾	.....	1	60		do	
Lastrea sp	¾	.....	1	70		do	
Do	¾	.....	1	68		do	
Nephrolepis scottii	¾	.....	1	55		do	
Nephrolepis scholzelii	¾	.....	1	55		do	
Nephrolepis whitmanii	¼	.....	1	62		do	
Do	¾	.....	1	68		do	
Polystichum sp	¼	.....	1	70		do	
Do	½	.....	1	60		do	
Pteris sp	½	.....	1	60		do	
Ficus utilis	.....	1⅞	1	73		Slight burning of new growth.	
Ficus sp	.....	2½	¾	.....	Cottony scale	No burning	All stages except eggs killed.

[1] *Asparagus plumosus* and *A. sprengeri* belong to the Lily family and are to be found under *Asparagus*.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				° F.			
Ficus sp.	.....	7½	1	----	Thread scale.	Severe burning; all leaves knocked. Injury largely due to close proximity of generator to plant.	All stages killed.
Forgetmenot	.....	7½	1	----	.....	Severe burning of tender foliage.	
Forsythia viridissima	.....	1¼	½	----	Aphids	No burning	100 per cent killed.
Freesia	½	.....	1	60	.....	.....do.....	
Do	¾	.....	1	60	.....	.....do.....	
Fuchsia	½	.....	1	60	Greenhouse white fly.	.....do.....	All stages except eggs and late pupæ killed.
Do	¾	.....	1	68	.....do.....	.....do.....	Do.
Do	.....	5	¾	66	.....	Slight burning	
Gaillardia sp	½	.....	1	62	.....	No burning	
Gardenia	½	.....	1	60	.....	.....do.....	
Do	¾	.....	1	68	.....	.....do.....	
Do	.....	5	¾	66	.....	.....do.....	
Do	.....	7½	1	----	.....	Slight burning	
Genista	¾	.....	1	55	.....	No burning	
Do	.....	5	¾	66	.....	Flowers burned.	
Geraniums:							
Martha Washington	½	.....	1	70	Aphids	New growth burned.	60 per cent killed.[1]
Do	½	.....	1	70	.....do.....	.....	100 per cent killed.[1]
Peppermint	½	.....	1	70	.....	No burning	
Do	¾	.....	1	68	.....	.....do.....	
Bedding	½	.....	1	60	Greenhouse white fly.	.....do.....	All stages except eggs and late pupæ killed.
Do	¾	.....	1	68	.....do.....	.....do.....	Do.
Rose	½	.....	1	64	.....	New growth burned.	
Gladiolus	½	.....	1	62	.....	No burning	
Do	¾	.....	1	55	.....	.....do.....	
Heather (Scotch)	½	.....	1	70	.....	.....do.....	
Do	¾	.....	1	68	.....	.....do.....	
Do	.....	5	¾	52	.....	Slight burning	
Do	.....	7½	¾	----	.....	.....do.....	
Heliotrope	½	.....	1	64	.....	No burning	
Do	¾	.....	1	60	.....	.....do.....	
Hibiscus sp	¾	.....	1	60	.....	.....do.....	
Do	¾	.....	1	55	.....	.....do.....	
Hyacinth (water)	¾	.....	1	64	.....	.....do.....	
Do	¾	.....	1	55	.....	.....do.....	
Hydrangea (French variety).	½	.....	1	64	.....	.....do.....	
Do	¾	.....	1	60	.....	.....do.....	
Ilex sp. (English)	.....	5	¾	52	.....	.....do.....	
Do	.....	7½	1	----	.....	.....do.....	
Impatiens sultani	½	.....	1	66	Aphids	.....do.....	100 per cent killed.
Do	¾	.....	1	68	.....	.....do.....	
Ipomoea sp. (morning glory).	½	.....	1	64	.....	.....do.....	
Do	¾	.....	1	60	.....	.....do.....	
Iris (Spanish)	½	.....	1	64	.....	.....do.....	
Do	.....	5	¾	66	.....	Tips burned	
Lantana sp	½	.....	1	60	*Orthezia*	No burning	70 per cent killed.
Do	¾	.....	1	56	.....	.....do.....	
Laurus nobilis	.....	5	¾	52	Soft brown scale.	.....do.....	Immature stages killed.
Do	.....	7½	1	----	.....do.....	.....do.....	90 per cent killed.

[1] The difference in results noted was due to the difference in the tightness of the two houses.

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
Lilies:				°F.			
Lilium formosum	½	.....	1	60	Aphids	No burning	100 per cent killed.
Do	¾	.....	1	60	.....	do	
Lilium multiflorum	½	.....	1	60	Aphids	do	Do.
Do	¾	.....	1	60	.....	do	
Chinese	½	.....	1	55	.....	do	
Water	.....	5	¾	66	.....	do	
Loquat	.....	1¾	1	73	.....	Slight burning	
Mango	½	.....	1	60	.....	No burning	
Do	¾	.....	1	55	.....	do	
Do	5	.....	½	....	Aphids	Slight burning	Do.
Marguerite	½	.....	1	70	do	No burning	Do.
Do	½	.....	1	60	Hemispherical scale.	do	95 per cent of immature scales killed.
Do	¾	.....	1	68	.....	do	
Marigold (French)	½	.....	1	60	.....	do	
Do	½	.....	1	64	.....	do	
Mignonette	½	.....	1	60	.....	do	
Mimulus moschatus	½	.....	1	70	.....	do	
Do	¾	.....	1	56	.....	do	
Moon vine	½	.....	1	60	.....	Open flowers burned.	
Do	¾	.....	1	60	.....	Flowers and buds burned.	
Narcissus poeticus	¾	.....	1	55	.....	No burning	
Narcissus barri	½	.....	1	55	.....	do	
Nasturtium	½	.....	1	55	.....	do	
Nigella	½	.....	1	62	Aphids	do	100 per cent killed.
Do	.....	1½	½	....	.....	do	
Oleander	½	.....	1	66	.....	do	
Do	.....	5	½	76	.....	do	
Olive	.....	½	½	....	.....	do	
Orchid:							
Cattleya trianae	½	.....	1	64	.....	do	
Oxalis (flowering)	½	.....	1	58	.....	do	
Do	¾	.....	1	56	.....	do	
Palms:							
Areca lutescens	¾	.....	1	60	.....	do	
Chamaerops pumila	½	.....	1	66	.....	do	
Do	½	.....	1	77	.....	do	
Cocos sp	.....	½	½	....	.....	do	
Kentia belmoriana	½	.....	1	60	.....	do	
Do	¾	.....	1	60	.....	do	
Latania sp	¾	.....	1	60	.....	do	
Phoenix canariensis	.....	5	¾	66	.....	do	
Pandanus graminifolius	½	.....	1	70	.....	do	
Do	¾	.....	1	68	.....	do	
Pandanus veitchi	½	.....	1	70	.....	do	
Do	¾	.....	1	68	.....	do	
Pansy	½	.....	1	62	Aphids	do	Do.
Do	¾	.....	1	55	do	do	Do.
Pelargonium odoratissimum	.....	1½	1	73	.....	Slight burning	
Pelargonium sp	½	.....	1	62	.....	No burning	
Do	¾	.....	1	68	Aphids	do	75 per cent killed.
Pentstemon	.....	5	¾	52	.....	do	
Do	.....	7½	1	....	.....	Slight burning	
Persea americana	.....	¾	1	55	Hemispherical scale.	No burning	100 per cent immature scales killed.
Do	.....	1¾	1	73	.....	Slight burning	
Do	.....	¾	1	66	Avocado white fly.	No burning	All stages except eggs and late pupæ killed.
Petunia	½	.....	1	60	.....	do	
Poinsettia	½	.....	1	62	.....	do	
Pomegranate	.....	¾	....	....	.....	do	
Poppy (Shirley)	½	.....	1	60	.....	do	

TABLE I.—*Plants and insects fumigated with hydrocyanic-acid gas in greenhouses*—Continued.

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				° F.			
Primula chinensis	¼		1	58		No burning	
Do	½		1	56		do	
Do		5	¾	66		do	
Primula malacoides	¾		1	55		do	
Primula obconica	½		1	58	Greenhouse white fly.	do	All stages except eggs and late pupæ killed.
Do	¾		1	55		do	
Psidium guajava		⅝	½			do	
Do		1½	½		Long scale	do	Immature stages killed.
Rhododendron		5	¾	66		do	
Rhyncospermum sp		7½	1			do	
Rosemary	½		1	64		do	
Do	½		1	76		do	
Rose	½		1	64		Tender growth burned.	
Do	½		1	62	Rose leafhopper.	do	100 per cent killed.
Do		1½	1	73		do	
Sage, scarlet	½		1	74		No burning	
Do	½		1	60		do	
Do	½		1	60		do	
Schizanthus sp	½		1	60		do	
Do	½		1	56		do	
Scilla nutans	½		1	55		do	
Smilax		5	¾	52		do	
Do		7½	1			Severe burning.	
Snapdragon	½		1	60		Tender tips burned.	
Do	¾		1	60		do	
Spiraea cantoniensis		1½	½		Aphids	No burning	Do.
Spiraea latifolia		1½	½		do	do	Do.
Spiraea thunbergii		1½	½		do	do	Do.
Spiraea vanhouttei		1½	½		do	do	Do.
Spiraea sp	¾		1	60		do	
Stephanandra flexuosa		1½	½		Aphids	do	Do.
Stephanotis floribunda		5	¾	66		do	
Stevia sp	½		1	60		do	
Stocks	½		1	62		do	
Sweet peas	½		1	62	Aphids	Tips and blossoms burned.	Do.
Thunbergia erecta	½		1	64		No burning	
Do	½		1	76		do	
Tulip	½		1	55		do	
Verbena	½		1	64		do	
Do	½		1	60		do	
Verbena (lemon)	½		1	64		Tender growth burned.	
Vinca major variegata	½		1	58		No burning	
Do	¾		1	56		do	
Do		5	¾	66		do	
Vinca rosea	½		1	60		do	
Do	½		1	60		do	
Wandering Jew	½		1	64		Severe burning.	
Yucca		5½	¾			No burning	

PLANTS AND INSECTS FUMIGATED IN FUMIGATION BOX.

To determine the susceptibility of the plants listed in Table II, these plants were fumigated in an air-tight box under favorable conditions. Not only were they fumigated in an inclosure much tighter than a greenhouse, but they also received dosages much in excess of those commonly used in greenhouse work.

TABLE II.—*Plants and insects fumigated with hydrocyanic-acid gas in fumigation box.*

Name of plant.	Rate in ounces per 1,000 cubic feet.		Exposure in hours.	House temperature.	Infestation.	Results of treatment.	
	Sodium cyanid.	Potassium cyanid.				On plants.	On insects.
				°F.			
Alternanthera sp	.....	5	½	76	.....	No burning	
Do	.....	10	1	73	.....	do	
Amaranthus sp	.....	3½	½	....	.....	do	
Arenga mindorensis	.....	5	1	65	Long scale	do	100 per cent killed.
Atalantia glauca	.....	5	½	76	.....	do	
Do	.....	10	1	73	.....	do	
Banana	.....	10	¾	....	Citrus mealy bug.	Tender foliage burned.	Do.
Do	.....	5	1	....	do	No burning	95 per cent killed.
Belou glutinosa	.....	10	1	73	.....	do	
Carnation	.....	5	½	76	.....	Tender foliage burned.	
Catha edgmuthi	.....	2½	¾	....	Long scale	No burning	60 per cent killed.
Croton	2½	.....	¾	60	do	do	Do.
Do	5	.....	¾	66	do	do	100 per cent killed.
Do	10	.....	¾	68	do	do	Do.
Ferns:							
Boston	2½	.....	1	60	Larvæ Florida fern caterpillar.	do	40 per cent killed.
Do	5	.....	¾	62	do	do	100 per cent killed.
Do	7½	.....	¾	68	do	do	Do.
Do	10	.....	1	68	do	Tender growth burned.	Do.
Do	.....	5	½	76	Aspidistra scale.	No burning	All stages except egg killed.
Adiantum cuneatum	2½	.....	1	60	Larvæ Florida fern caterpillar.	do	40 per cent killed.
Do	5	.....	¾	62	do	do	100 per cent killed.
Do	7½	.....	¾	68	do	do	Do.
Do	10	.....	¾	68	do	Tender growth burned.	Do.
Nephrolepis whitmanii	5	.....	¾	66	do	No burning	Do.
Opuntia	.....	5	½	....	.....	do	
Do	.....	10	½	....	.....	do	
Orchids (in growing condition):							
Angraecum eburneum	5	.....	1	62	*Diaspis* sp	Slight burning.	Do.
Cypripedium sp	5	.....	1	62	.....	No burning	
Coelogyne flaccida	5	.....	1	62	Chaff scale	do	Do.
Coelia baueriana	5	.....	1	62	.....	do	
Dendrobium fimbricatum.	5	.....	1	62	*Lepidosaphes* sp.	do	Do.
Schomburgkia undulata	5	.....	1	62	.....	do	
Orchids (dormant):[1]							
Cattleya trianae	20	.....	¾	70	.....	do	
Cattleya sp	.....	20	½	....	.....	do	
Do	.....	21	1	....	.....	do	
Do	.....	42	½	....	.....	Slight burning; plant recovered.	
Osbeckia stellata	.....	5	1	58	Long scale	No burning	Do.
Palms:							
Kentia belmoreana	.....	5	½	....	Palm mealy bug and palm aphids.	do	Do.
Areca lutescens	.....	10	1	65	Tessellated scale.	Old foliage burned.	Do.
Corypha elata	.....	5	1	58	Long scale	No burning	Do.
Phoenix sp	.....	10	1	73	.....	do	
Pandanus veitchii	.....	10	1	73	Florida red scale.	do	Do.

[1] Imported orchids without new growths.

In order that there may be no confusion on the part of the reader as to the insects referred to in the tables by their common names, both their common and scientific names are listed herewith:

Greenhouse white fly	*Trialeurodes vaporariorum* (Westw.).
Citrus mealy bug	*Pseudococcus citri* (Risso).
Long-tailed mealy bug	*Pseudococcus adonidum* (L.).
Palm or avocado mealy bag	*Pseudococcus nipae* (Mask.).
Greenhouse Orthezia	*Orthezia insignis* (Dougl.).
Florida red scale	*Chrysomphalus ficus* (Ashm.)
Long scale	*Coccus elongatus* (Sign.).
Soft brown scale	*Coccus hesperidum* (L.).
Palm aphis	*Cerataphis latanae* (Boisd.).
Hemispherical scale	*Coccus hemispherica* (Targ.).
Florida fern caterpillar	*Eriopus floridensis* (Guen.).
Aspidistra scale	*Hemichionaspis aspidistrae* (Sign.).
Tessellated scale	*Eucalymnatus tessellatus* (Sign.).
Azalea Eriococcus	*Eriococcus azaleae* (Horv.).
Azalea lacewing	*Stephanitis azaleae.* (Horv.).
Greenhouse thrips	*Heliothrips haemorrhoidalis* (Bouché).
Onion thrips	*Thrips tabaci* (Lind.).
Cottony scale	*Pulvinaria* sp.
Thread scale	*Ischnaspis longirostris* (Sign.).
Avocado white fly	*Trialeurodes floridensis* (Quaint.).
Rose leafhopper	*Typhlocyba rosae* (L.).
Chaff scale	*Parlatoria proteus* (Curt.).

CONCLUSION.

The results indicated in the foregoing pages are for the most part based on the fumigation of commercial houses under commercial conditions. The slight variations in the percentage of insects killed and injury to plants may be accounted for by the tightness or lack of tightness of different houses. It is obvious, therefore, that it is not practicable to give specific directions as to the amount of cyanid to be employed under all conditions. A knowledge of the pests to be controlled and of the condition of the plants and tightness of the house under consideration will render it possible to determine the dosage to be used.

In fumigating a house containing a large variety of plants, using the correct dosage and under proper conditions, it happens occasionally that some plants appear to have been injured. However, this injury is not permanent, as the plants will show new vigorous growth in a short time. Repeated tests have demonstrated thoroughly that the growth of many plants is stimulated by hydrocyanic-acid gas.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 535

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ June 28, 1917

THE HORSE-RADISH FLEA-BEETLE: ITS LIFE HISTORY AND DISTRIBUTION.

By F. H. CHITTENDEN, *Entomologist in Charge of Truck Crop and Stored Product Insect Investigations*, and NEALE F. HOWARD, *Specialist*.

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INTRODUCTORY.

Nearly every year there is brought to this country some insect immigrant, and frequently, in the course of time, these immigrants prove to be pests. As a rule, they are introduced through the large seaports, particularly Boston, New York, New Orleans, and San Francisco, from which points they spread westward, northward, or southward, and less frequently eastward. Occasionally such an insect is carried by commerce beyond the coasts and makes its first appearance inland. This happened in the case of the insect to which the senior author has given the name of the horse-radish flea-beetle (fig. 1) and which is known zoologically as *Phyllotreta armoraciae*

NOTE.—Horse-radish is widely cultivated in the United States and especially where the horse-radish flea-beetle is now most injurious. The farm value of horse-radish is not far from $400,000 per annum, considering its growth for home use. Two other insects than the horse-radish flea-beetle are especially attracted to it, the horse-radish webworm (*Plutella armoracia* Busck) and the horse-radish caterpillar (*Evergestis straminalis* Hübn.). Neither of these is of any importance, but in the southern range of growth of horse-radish the harlequin cabbage bug is a most destructive pest, seeming to prefer this plant to other crucifers. The horse-radish flea-beetle will continue to spread and soon become a dangerous pest unless growers practice methods of control.

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Koch.[1] It was obtained for the first time in 1893 on the withered leaves of horse-radish in a vacant lot within a fourth of a mile of the grounds of the Columbian Exposition at Chicago, Ill. It is possible that the species was actually introduced at about that time, but probably the time was one, two, or more years earlier, and it was not reported as a pest until 1908.

The larvæ as well as beetles live on the leaves and petioles of the common horse-radish ([*Nasturtium*] *Radicula armoracia*) and when numerous injure the plant to such an extent as to reduce materially the root crop. The larvæ mine the petioles or midribs (fig. 2), while the adults feed on the leaves, causing the characteristic flea-beetle injury—withering and dying—or gouge deep pits in the petioles or midribs.

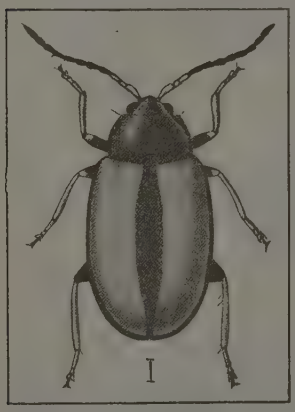

FIG. 1.—The horse-radish flea-beetle (*Phyllotreta armoraciae*): Adult. Greatly enlarged. (Original.)

This beetle belongs to the same genus as the well-known injurious striped cabbage flea-beetle (*Phyllotreta vittata* Fab.) but may be distinguished readily from all other species occurring in this country by its elytra or wing-covers, which are mostly of a pale cream color with a comparatively narrow sutural black stripe, as shown in figure 1.

The horse-radish flea-beetle, having recently become an economic factor in the growing of horse-radish[2] on a commercial scale in Brown County, near Green Bay, Wis., the junior author has been able to trace its life economy and history. It first appeared in sufficient numbers to be seriously injurious in the summer of 1914, when it was reported and observed by Prof. J. G. Sanders. In the two years following, the beetles reappeared in large numbers in the same locality.

While as yet not very generally distributed and confined to attacks on the relatively unimportant crop of horse-radish, the possibility that this insect in its new domain may adapt itself to the other and more important members of the cultivated cruciferous plants renders it worthy of such notice as can be supplied.

[1] Order Coleoptera, family Chrysomelidae, subfamily Halticini.

[2] The authors desire to acknowledge the cooperation of the Department of Economic Entomology, University of Wisconsin, and the many favors received from Mr. George B. Smith, Green Bay, Wis., on whose farm the junior author was stationed when many of the data in this paper were obtained.

DESCRIPTIVE.

THE ADULT.

In appearance *Phyllotreta armoraciae* is distinct from any species of flea-beetle belonging to or introduced into this country. It is somewhat larger and wider than any of the native species of the genus. It is of oval form, strongly convex, and black in color. The first three antennal joints, the apices or tips of the four anterior femora, the tibiæ, and the tarsi are reddish yellow. The elytra are very light yellowish, or cream color, nearly white, with a very thin black lateral margin and a broadened sutural stripe, widest at the middle and constricted at each end and extending from the base of the thorax to the apex of the elytra, where it joins the lateral line. The frons or front is very finely, and the prothorax and elytra densely, punctate. A sensitive pore from which proceeds a seta is located on the lateral margin, which is behind the anterior angle. In the male the fourth antennal joint is slightly thickened and longer than the fifth. In the female the fourth and fifth joints are equal.

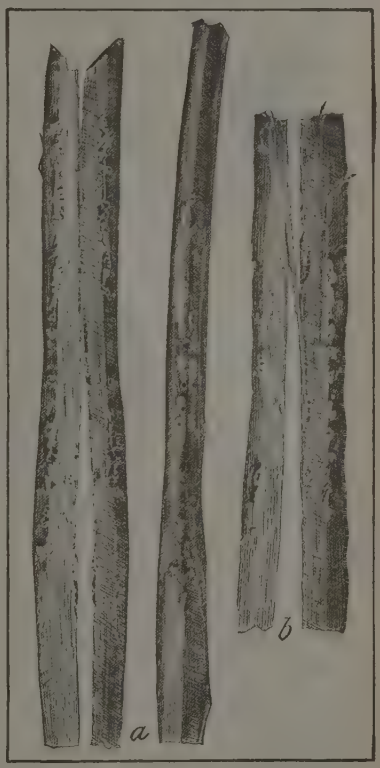

FIG. 2.—Work of the horse-radish flea-beetle in leaf petioles of horse-radish. (Original.)

The average length is from 3 to 3.3 mm., but individuals have been observed where there is a variation of from 2.6 mm. to 3.4 mm. and a variation in width of 1.3 mm. to 1.9 mm.

The following synonymy is recognized:

Phyllotreta armoraciae (Koch).

Haltica armoraciae Koch, Entom. Hefte, v. 2, p. 75, 1803.

Haltica vittata Steph., Mandibulata, p. 292, 1831.

The species is also treated systematically by Illiger, Duftschmidt, Gyllhenhal, Schilling, Redtenbacher, Seidlitz, Foudras, Allard, Leesberg, and others.

THE EGG.

The egg (fig. 3) is oval, capsule-like, deep orange in color, with no special characteristic marking or reticulations visible under a 4-millimeter objective. The following are the measurements taken from 22 eggs: Maximum, 0.47 mm. by 0.84 mm.; minimum, 0.26 mm. by 0.43 mm.; average, 0.33 mm. by 0.57 mm.

FIG. 3.—The horse-radish flea-beetle: Egg. Highly magnified. (Original.)

THE LARVA.

The immature larva.—The larva, just after hatching from the egg, is about 1.3 mm. long by 0.2 mm. wide; the color of the entire body is whitish, the head, thoracic plates, and anal plate varying from whitish to pale brown. Within a few hours the head, thoracic plate, and anal plate become darker, and a day or more later turn deep brown. In other major respects, excepting the numerous transverse wrinkles and the relative proximity of the setæ, the young larva is very similar to the older larva.

The mature larva.—The larva (fig. 4), when full grown, is slender subcylindrical, pale yellowish white, with dark brown head, thoracic plate, and anal plate; mandibles distinctly quadridentate; head with the usual V-shaped epicranial suture and dark median line caused by attachment of tentorium; five setæ on epicranium each side of median line, several setæ distributed irregularly about lateral margins of head as shown in figure 4; thoracic plates divided by distinct suture; row of three setæ along anterior lateral margin of each plate; one on lateral posterior angle; four minute setæ on posterior inner margin of each plate; one seta on inner anterior angle; mesothorax with pale chitinous plates bearing setæ, two in anterior row, four in posterior row, four on slightly elevated pleural area; metathorax similar. The thoracic legs each bear one claw.

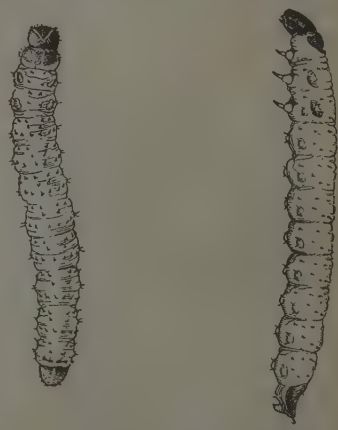

FIG. 4.—The horse-radish flea-beetle: Larva; at left, dorsal view; at right, lateral view. Tubercles and tuberculiferous hairs more prominent than in nature to show arrangement. (Enlarged.) (Original.)

The abdominal segments bear dorsally three rows of slightly elevated chitinous plates, each of which gives rise (when not continuous) to a seta; the first row comprises six, the middle row two, the

third row four; at the ends of the third row, a little anterior, are the slightly elevated chitinous pleural plates, bearing three setæ each.

The anal plate approximates a rectangle in outline with the sides converging toward the posterior end and corners rounded. The whole surface except the chitinous plates is covered with minute granulations.

The length just prior to pupation is 4.8 mm., the width 0.8 mm.

THE PUPA.

The pupa (fig. 5) is white and about the same size as the mature beetle. The antennæ are placed along the dorsal margin of the wings and extend around on the ventral side about one-half way to the middle of the body. Between the wings, which extend down to the fourth abdominal segment, is a narrow space in which the tarsi of the three pairs of legs are placed. The femora and tibiæ of the anterior pairs of legs are parallel and extend transversely across the body over the wings, while these parts of the posterior pair of legs extend obliquely and are under the wings, the tips being just visible. Two forceps-like chitinous processes occur at the apex or tip of the last abdominal segment; a stout seta on the tip of each femur, and a number of setæ at various points on the head and body.

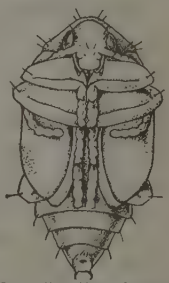

FIG. 5.—The horse-radish flea-beetle: Pupa, ventral view. Enlarged. (Original.)

DISTRIBUTION IN NORTH AMERICA.

The following is a list of localities in which the horse-radish flea-beetle is known to occur in North America. (Fig. 6.) This list is given in approximate order of the first noted appearance of the insect, with the name of the collector in each case:

Chicago, Ill., 1893 (Chittenden).
Guttenberg, Iowa, 1894 (Hugo Soltau).
Okauchee, Wis., 1896 (Dr. E. G. Love).
Dane County, Wis., 1900 (Dr. Wm. S. Marshall).
Bloomington, McLean County, Ill., 1900 (Wolcott).
Glencoe, Ill., 1908 (J. E. Fehd).
Milwaukee County, Wis., 1908 (Dr. S. Graenicher).
Whitewater, Wis., 1909 (Univ. Wis. Coll.).
Westmount, Quebec, 1910 (A. F. Winn).
Lake County, Ind., 1910 (Wolcott), (Blatchley).
Shermerville, Ill., 1912 (Retzinger).
Chester, N. J., 1913 (H. O. Marsh).
Green Bay, Wis., 1914 (J. G. Sanders), 1915 (N. F. Howard).
Highland Park, Mich., 1915 (L .Miller).
Omaha, Nebr., 1915 (Ehlers).
Potsdam, N. Y., 1915 (Chas. Dury).
Ashtabula County, Ohio, 1915 (Robt. Sim).
Madison, Wis., 1916 (N. F. Howard).

ORIGIN AND DISSEMINATION.

The horse-radish flea-beetle is of European origin, and was first described by Koch in 1803[1] from Germany. It is a well-known species in the Old World, and its specific name is derived from its favorite food plant (*Nasturtium*) *Radicula armoracia*. Like all of the striped flea-beetles of the true genus Phyllotreta, the present species breeds on cruciferous plants.

As to the means of introduction of this species in the heart of this country, it was probably brought in with horse-radish and less probably in marsh cress (*Radicula palustris*), or possibly with some potted plant. It is not impossible that these plants were brought to America expressly on account of, if not actually for, exhibition at

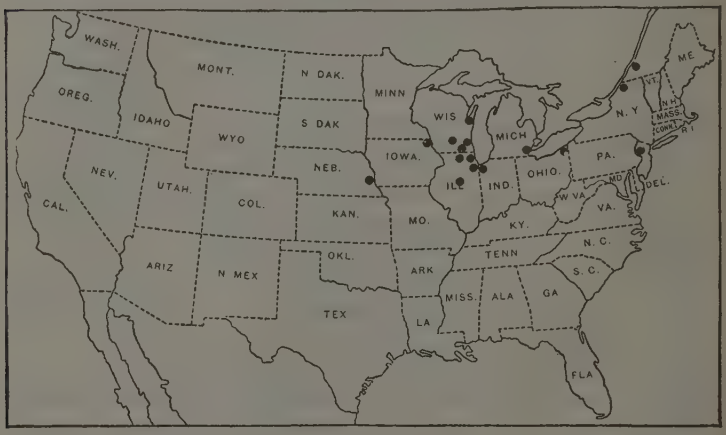

FIG. 6.—Map showing present known distribution of the horse-radish flea-beetle. (Original.)

the Columbian Exposition. It is remarkable, however, in being introduced, not near a seaport, but so far inland.

In the place of its nativity this species ranges throughout middle Europe. Among early records of its establishment in the United States are Guttenberg, Iowa; Chicago and Bloomington, Ill.; and Okauchee, Wis., about 30 miles due west of Milwaukee, and in 1896 there was a strong probability that it would soon spread to Missouri and perhaps to southern Minnesota and Michigan—in other words, that it would establish itself in the course of time in the upper Austral and, perhaps, a portion of the Transition region in the vicinity of its known range at that time. This would include Nebraska in the West and Ohio in the East. The natural progress of most insects introduced from Europe is westward, but there are several

[1] Numbers in parentheses refer to "Bibliography," p. 15.

examples, notably the Colorado potato beetle, of an insect pest which has first traveled eastward.

The predictions made in 1896 that the horse-radish flea-beetle probably would spread soon to southern Minnesota and Michigan were practically correct, as the species is known to be near the State line of Minnesota in Iowa. It had reached Michigan by 1915 and had spread to Ohio and Nebraska the same year. That it would take an eastward sweep as far as Potsdam, N. Y., Quebec, Canada, and northern New Jersey was scarcely expected for years to come. It is now near the border line of Pennsylvania and will undoubtedly spread to that State and to southern New York. The tendency is northward rather than southward, Bloomington, Ill., being the most southerly locality from which it has been reported.

Until otherwise known (and there is little likelihood of learning anything more definite with regard to the first appearance of the horse-radish flea-beetle), it must be concluded that this species was introduced first into Illinois in or around Chicago. From this center it has spread westward and northward, and has evidently taken large commercial jumps eastward, or has been introduced into New Jersey independently, but has made little progress to the south. From present knowledge it apparently prefers the regions about the Great Lakes, but in time doubtless it will be quite as numerous in other waterways and tributaries, even in moist places generally, which are the natural habitat of its principal food plants—horse-radish and marsh cress. In the course of time the somewhat scant records doubtless will be greatly enlarged, showing thereby a more general distribution than is known at present. It has been remarked that in Wisconsin, in the Green Bay region, conditions for the development of this species are highly favorable. This is in the northern portion of the Transition Life Zone, while Quebec is in the Canadian portion of the Boreal Zone.

REVIEW OF LITERATURE.

An account of the horse-radish flea-beetle was given by the senior author in 1895, which is now out of print (3).[1] In this article mention was made of the first occurrence of the species in this country and of the European literature, and the insect was compared with other species of its genus. The original technical description was published in 1803 (1). In 1893 Julius Weise (2) gave a systematic and detailed description of the species with biologic notes and bibliography. In 1897 (4) the senior author noted the occurrence of this insect in Wisconsin in 1896 and suggested the probable range

[1] Figures in parentheses refer to Bibliography, p. 15.

of the species. In 1900 A. B. Wolcott (5) made mention of the capture of the beetle at Bloomington, Ill. Injury by this species was briefly mentioned by J. J. Davis in Illinois in 1910 (6). In 1910, also, Blatchley (7) recorded its occurrence in Lake County, Ind., and in 1911 A. F. Winn (8) observed it at Westmount, Quebec, Canada, on horse-radish received from Montreal. It is not stated, however, whether the insect was believed to come from Montreal or from Westmount. In Europe brief notes were published by Heikertinger in 1911 and 1912 (9, 10).

FOOD PLANTS.

This beetle is partial to horse-radish and marsh cress. It was taken once on young cabbage in hotbeds in early spring by the junior author but was not observed to be eating. The future no doubt will reveal the possibility at least of other host plants.

SEASONAL HISTORY.

THE EGG.

The eggs are deposited from the latter part of April or early May through spring and summer until early August. The manner of placing and the position are variable, but the preferred location is on the tender petioles of young leaves, in the crevices where they leave the root. A few eggs have been found on the ground and on different places on the leaves, above and below the ground, and also carefully placed in the pits made in the stems and petioles by the larvæ or adults. They usually occur in small masses, either carefully arranged side by side in single rows, or two rows high, or carelessly piled without order. Occasionally an egg is found standing on end. The attachment to the plant is not very secure and often an egg-mass falls on the slightest disturbance. In the cages from 2 to 26 eggs were laid at intervals by a single female. While the most frequent number of eggs deposited was 22, at times 44 were deposited, indicating that about 22 eggs are developed in the ovarian tubes at one time. Copulation often takes place between deposition of batches of eggs, but it has not been determined whether or not this is necessary before the deposition of each batch. Judging from analogy, however, it may not be necessary. Hundreds of eggs were obtained in the insectary, but the egg record of one gravid female (Table 1) will suffice to show the egg-laying capabilities of the species. This female was placed in a vial with a portion of horse-radish leaf May 1, 1915, and the total number of eggs laid was 418.

TABLE 1.—*Egg record of a single female horse-radish flea-beetle.*[1]

Date.	Number of eggs deposited.	Remarks.
May 17	22	
27	22	
28	17	
June 3	23	Within 48 hours.
7	26	
8	2	
14	4	
17	.....	Male added.
21	25	
22	.....	Copulating.
25	44	Within 48 hours.
27	24	
29	44	Within 48 hours.
30	.....	Copulating.
July 1	28	Hatched July 12.
2	21	
3	22	
12	39	Within 72 hours.
14	.....	Mass; not counted; estimated at 22.
17	.....	Copulating; eggs laid about July 11 hatched.
18	.....	Copulating.
22	7	Copulating; within 36 hours.
30	26	Within 5 days.
Aug. 3	22	Within 72 hours.
7	.....	Female dead; male still alive.

[1] Within 24 hours in each case, unless otherwise mentioned, eggs were always removed.

Incubation.—The incubation period of the egg varied from 7 to 14 days, as the following data show:

TABLE 2.—*Incubation period of eggs of horse-radish flea-beetle.*

Number deposited.	When deposited.	Date of hatching.	Incubation period.	Larvæ working.
			Days.	
20	May 1	Before May 17	14 (approximate)	May 17.
(?)	do	May 11	10	
39	May 11	May 25	14	
28	July 1	July 12	11	
	July 10, 11, 12	July 17	7 (approximate)	
13	June 27	July 4 or 5	8 (approximate)	

The months of May, June, July, and August were from 3.6° to 5° F. below normal.

THE LARVA.

On hatching the young larva crawls about the leaf for some time. Several individuals, observed over an hour, showed no particular course. Some went up toward the tip, others toward the crown, where they were lost from sight, but none started feeding. A small, tender petiole, recently invested by numerous larvæ, showed that they had entered at different places along the inner side.

As the larvæ grow and feed in the tissues of the petioles and midribs of the leaves, their presence is indicated by darkened or dead areas, where they have approached the surface. When the larvæ are

very numerous, the petiole is tunneled to the extent that it shrinks considerably and causes the leaf to wither and die at the tip and about the margins. When the larva is ready for pupation, it leaves the petiole and enters the ground. The exit holes, which soon collapse and appear as brown spots, are also characteristic of larval injury.

When both larvæ and adults occur together, the former are the more injurious. The injury which the adults cause to the young shoots early in spring as they are breaking through the soil is possibly more serious than subsequent injuries.

That the larva may live in the roots of the plant has been clearly demonstrated since it was first reported to the senior author. A potted plant died and was left intact for about a month. When the pot was wanted for another experiment the soil was found to contain several larvæ and pupæ. Only the shell of a root remained, the contents having been completely devoured by the larvæ. The pupæ transformed to normal adults shortly afterward. This habit of descending to the roots is not very general, however, for it has never been observed while roots peeled for the shredder were being examined.

After leaving the plant the larva enters the soil to a depth of from one-eighth to one-fourth of an inch or even 3 inches. Here it remains for 4 or 5 days, when it becomes white and short and thick. In this form it is inactive. From 2 to 6 days, usually 3 or 4, intervene before pupation.

The total larval period of an individual which was deposited as an egg on May 1, and which was hatched about May 15, was 48 days (about May 15 to about July 6). Another required 52 days; two others required about 57 days, two others 64 days, and two others 66 days.

The two larvæ which developed in 48 and 52 days, respectively, each remained 10 days in the pupal stage. Three other individuals also passed the pupal stage in 10 days, but one required 12 days, while three required from 12 to 13 days.

On September 11, 1915, a few pupæ in the cages had not yet transformed. April 17, 1915, the adults were already numerous about the ground where the shoots of horse-radish were just appearing, or about to appear.

This flea-beetle, like others of its kind, and like most leaf-beetles, hibernates in the adult stage. Careful search for pupæ from time to time practically proves this.

In Wisconsin only one generation appears annually.

The total period of time from egg laying to adult ranges from 77 days to about 90 days in the cases where complete records were obtained. Repeated attempts to obtain eggs from the adults of the current season failed.

The length of the egg-laying period, as shown by the record of an individual given above, is about 75 days, from the middle of May to the first of August. It is certain that this beetle emerged in 1914, probably in August or the first of September, and it is fair to assume that the species would have lived longer in nature had it not been killed by predators, parasites, disease, or the like. This shows the species to be exceptionally long-lived, living about a year in the adult stage.

The fact that the males are as long lived as the females may possibly be due to the fact that copulation is necessary at intervals during the egg-laying period.

RECORD OF EXPERIMENTS IN 1916 AT GREEN BAY AND MADISON, WIS.

April 24, a pair of beetles confined with horse-radish plants.
April 30 to May 5, copulation observed.
May 11, 15 eggs deposited within 24 hours or less.
May 12, 12 eggs in fold of leaf; might have been overlooked the day before.
May 17, 31 eggs found deposited since May 12.
May 22, 24 eggs found over Sunday, about 48 hours.
May 24, 20 eggs and copulation observed.
May 25, 25 eggs observed.
May 29, 48 eggs obtained over Sunday in about 48 hours.
May 31, moved to Madison, Wis.
June 4, 66 eggs obtained since May 30; copulation observed.
June 9, 44 eggs, approximately, observed since June 4.
June 14, 60 eggs found in 24 hours.
June 15, 49 eggs seen in about 24 hours.
June 21, 27 eggs obtained since June 15.
June 24, 44 eggs seen in 24 hours.
June 27, 48 eggs deposited within 24 hours or less. At this point the observations were discontinued.

HATCHING RECORD.

The same difficulty which was experienced in 1915 in the hatching of the eggs was observed this year. Of the entire number of eggs obtained from the female whose record is given above, a total of 513, the following hatched:

June 4, 1 egg deposited May 17 hatched, 17 days.
June 9, 1 egg deposited May 17 hatched, 22 days.
June 14, 7 eggs deposited June 9 hatched, 7 days.

As noted in the table of the 1916 records (Table 3), some of the larvæ died and only a few of these cases are mentioned; the remainder, being unimportant to the records, are not recorded. All dates on which observations were made are given.

TABLE 3.—*Life-history record of the horse-radish flea-beetle during 1916.*

Date eggs laid.	Date larva leaves plant.	Egg and larval stages.	Date of pupation.	Prepupal period.	Date of emergence.	Total pupal period.	Egg to adult.
		Days.		*Days.*		*Days.*	*Days.*
	July 20	52	July 20		Died		
	21	53	27	6			
	21	53	27	6	July 31	10	63
	24	56	27	3	31	7	63
	24	56	28	4			
			24		Died		
	July 27	59	31	4	Aug. 5	9	68
	27	59	31	4	7	11	70
	27	59	31	4	7	11	70
	27	59	31	4	2	7	66
	27	59	31	4	Died		
	27	59	31	4	Died		
			27		July 31[1]		63
			27		31[1]		63
			31		Aug. 5		68
	Aug. 28	60	Aug. 2	5	5	8	68
	28	60	2	5	Died		
	28	60	3?	6	Died		
	31	63			Aug. 5	6	68
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	31	63	5	5	13	13	75
	Aug. 2	65	7	5	Died		
May 29[1]	2	65	9	7	Died		
	2	65	Died				
	2	65	Died				
	5	68	Aug. 7	2	Died		
	5	68	9	4	Died		
	5	68	Died				
	5	68	Died				
	5	68	Died				
	5	68	Died				
			Aug. 5		Died		
	Aug. 7	70	13	6	Died		
	7	70	Died				
	9	72	Died				
	9	72	Died				
	9	72	Died				
	9	72	Died				
					Aug. 7		70
	Aug. 13	75	Aug. 20	7	Died		
	13	75	20	7	Died		
	13	75	20	7	Died		
			13		Aug. 20		83
			13		Died		
					Aug. 20		83
					20		83
			20		25?		88[1]

[1] Approximate.

SUMMARY OF TABLE.

Average combined egg and larval stages	days	61.4
Average prepupal period, 30 individuals	do	4.9
Average total pupal period, 12 individuals	do	10
Average egg to adult, 20 individuals	do	71.8

OTHER RECORDS.

Appearance record: First observed on leaves of horse-radish just breaking through the ground at Green Bay, Wis., April 20, 1916.
Copulation first observed May 2.

RECENT INJURY.

An account of recent injury by the horse-radish flea-beetle was received from a correspondent at Shermerville, Ill., who wrote January 3, 1917, substantially as follows, and who, later, furnished specimens:

I should like your advice on an insect which destroys my horse-radish. It is causing thousands of dollars loss every year in this community, and there seems

to be no way to destroy it. It is very small, yellow with black stripes, and it hops; inside of the leaves there are about 25 or 50, according to the size of the leaf. They do their damage when the horse-radish first sprouts after planting, eating off the sprouts as they come up. We have for years hauled out all old dead leaves, after marketing the horse-radish, and burned them. Paris green kills the leaves; kerosene solution does not kill the bug. Every year I plant about 35,000 plants, and the last two years only about 8,000 developed; besides the loss, I have less and less plants each year. There are several planters who have lost their entire crop on account of this insect.

NATURAL ENEMIES.

No parasite or disease of any sort has been observed in the field or in confinement. This is undoubtedly an oversight, since other flea-beetles have natural enemies, such as parasites of the adults, and in time these will probably come under observation. From Glencoe, Ill., a larva apparently predacious on the larva of this species was received.

ASSOCIATED INSECTS.

Associated with this species at Madison, Wis., were three species of minute maggots, (*Elachiptera*) *Crassiseta nigriceps* Loew, *Oscinis pallipes* Loew, and *Agromyza scutellata* var. *variegata* Meig. The first was found in horse-radish stems with the flea-beetle, and adults were reared from larvæ boring in the same stems, often in the same tunnels as the flea-beetle larva. The third species was reared in horse-radish flea-beetle rearing cages with the preceding. This and probably one or more related species have often been reared from horse-radish stems both at Green Bay, Wis., and Madison, Wis., but just what part they play in the economy of this beetle is unknown. The adults frequently annoy the beetles by flying around and apparently attempting to alight on them.

METHODS OF CONTROL.

SPRAYING.

The injurious flea-beetles of the group to which this species belongs have never been satisfactorily treated by means of insecticides, to the knowledge of the authors. The same applies to other groups of small flea-beetles which attack solanaceous plants, like potato and egg-plant. The powerful hind legs which enable these insects to jump like fleas assist them in escaping from plants during spraying operations, and it is a matter of general knowledge among practical entomologists that it can not be very well determined how much poison, if any, they obtain by feeding on the poisoned surface of leaves. Many experiments have been made, and in practically every case the results have been negative. On the other hand, where Bor-

deaux mixture has been applied, the flea-beetles of different groups are nearly always repelled. It is evident that arsenicals repel, but in the case of flea-beetles Bordeaux mixture is more effective, a fact which has been known for many years.

During the season of 1914, when injuries by the horse-radish flea-beetle in Wisconsin were very serious and the root crop was much reduced, it was found necessary to bring roots from farther south to supply the usual trade. At this time arsenate-of-lead paste, 6½ pounds to 50 gallons of water, was used four times with considerable success. In the spring of 1915 the field was plowed, the roots collected, stripped of every vestige of leaves, and planted about a quarter of a mile from the old bed. This reduced the beetles to such an extent that very little injury was apparent until the middle of June, 1915.

On June 23 the plants were sprayed with arsenate of lead, and the numbers were reduced considerably. About three weeks later the poison was applied again. In the latitudes of Wisconsin, Michigan, Ohio, Pennsylvania, Delaware, New York, Indiana, and Iowa the spray should be administered at intervals from about the last week in April until late in July.

VALUE OF CULTURAL PRACTICES.

The importance of the employment of methods for the control of these insects as pests is exemplified by the experience of a firm at Green Bay, Wis. Before the advent of flea-beetles, truckers were able to raise horse-radish on a large scale from the same beds for several years at a time, but now the abundance and destructiveness of this flea-beetle makes it necessary to change these cultural practices completely in order to produce a crop, and it is necessary to replant a new bed from old roots every season.

SUMMARY.

The growing of horse-radish in the North is menaced by the introduction from Europe of a small insect known as the horse-radish flea-beetle. The beetle is oval in outline, about one-eighth of an inch long, with yellow elytra or wing-covers bordered with black, and with a longitudinal black band through the middle. The larvæ or young bore into the petioles or midribs of horse-radish, and the adults feed on the leaves and gouge deeply into the midribs, causing drying and death.

The beetle was first recognized in this country at Chicago, Ill., in 1893, since which time its area of distribution has increased until it now occurs from New York and New Jersey to Quebec, Canada, and westward to Nebraska.

The species passes the winter in hibernation as a beetle, coming forth in its northern range in April and May.

While as yet destructive only to horse-radish, its capabilities of becoming a pernicious pest, should it adapt itself to the economically more important cruciferous crops, must be acknowledged, and measures should be taken for its suppression wherever possible.

No systematic control program has been adopted as yet. Bordeaux mixture, a powerful repellent against flea-beetles, applied on the first appearance of the insect will prevent much injury, and if arsenate of lead is used later it should hold the insect in check.

When a new bed is to be planted a location should be chosen as far removed as possible from any infested bed. It is advisable also to destroy all volunteer plants, not only to keep the insect in check but in some cases to suppress it as a weed.

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